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Morphometric MRI Changes After Posterior Fossa Decompression in Chiari Type I Malformation

Posterior Fossa Dekompresyonu Sonrası Chiari Tip I Malformasyonunda Morfometrik MRG Değişiklikleri

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Abstract

Objective: Chiari type I malformation (CM1) involves herniation of the cerebellar tonsils through the foramen magnum and altered cerebrospinal fluid (CSF) dynamics. Morphometric magnetic resonance imaging (MRI) measurements can objectively assess anatomical and physiological changes after posterior fossa decompression surgery (PFDS). This study evaluated postoperative morphometric alterations in CM1 and their implications for CSF flow.

Method: This retrospective study included 23 adult patients who underwent PFDS for CM1 between 2015 and 2024. Preoperative and postoperative mid-sagittal MRI images were analyzed to measure tonsillar ectopia (TE), displacement of the iter (DOI), and mammillopontine distance (MPD). Boogard's angle (BooA) was used as an anatomical reference for postoperative evaluation. Paired t-tests were used for comparison of morphometric parameters, with $p<0.05$ considered statistically significant.

Results: The mean age of patients was 34.0±8.7 years; 19 (82.6%) were female. The mean TE significantly decreased from 10.9±2.8 mm preoperatively to 6.9±2.5 mm postoperatively ($p=0.0003$). DOI also showed a significant reduction from 4.2±0.9 mm to 3.9±0.8 mm ($p=0.048$). No significant change was observed in MPD (6.2±0.7 mm vs. 6.1±0.7 mm, $p=0.324$).

Conclusion: PFDS effectively reduces tonsillar descent in CM1, confirming the anatomical decompression of the posterior fossa. The modest reduction in DOI suggests potential improvement in CSF flow, while stable MPD values indicate limited brainstem displacement. Larger prospective studies incorporating dynamic CSF

Öz

Amaç: Chiari tip I malformasyonu (CM1), serebellar tonsillerin foramen magnumdan aşağı herniasyonu ve buna bağlı beyin omurilik sıvısı (BOS) dinamiklerinde bozulma ile karakterizedir. Morfometrik manyetik rezonans görüntüleme (MRG) ölçümleri, posterior fossa dekompresyon cerrahisi (PFDC) sonrasında oluşan anatomik ve fizyolojik değişiklikleri nesnel olarak değerlendirmeye olanak sağlar. Bu çalışmada, CM1 hastalarında PFDC sonrası morfometrik değişikliklerin ve BOS akımı üzerindeki olası etkilerinin değerlendirilmesi amaçlandı.

Yöntem: Bu retrospektif çalışmaya, 2015-2024 yılları arasında CM1 nedeniyle PFDC uygulanan 23 erişkin hasta dahil edildi. Ameliyat öncesi ve sonrası orta sagital MRG kesitlerinde tonsiller ektopi (TE), iter deplasmanı (DOI) ve mamillopontin mesafe (MPD) ölçüldü. Postoperatif değerlendirmede anatomik referans olarak Boogard açısı (BooA) kullanıldı. Morfometrik parametrelerin karşılaştırılmasında eşleştirilmiş t-testi kullanıldı ve $p<0,05$ istatistiksel olarak anlamlı kabul edildi.

Bulgular: Hastaların ortalama yaşı 34,0±8,7 yıl olup, 19'u (%82,6) kadın ve 4'ü (%17,4) erkekti. Ortalama TE değeri ameliyat öncesi 10,9±2,8 mm iken ameliyat sonrası 6,9±2,5 mm'ye geriledi ($p=0,0003$). DOI değeri de 4,2±0,9 mm'den 3,9±0,8 mm'ye azaldı ($p=0,048$). MPD'de ise anlamlı bir değişiklik saptanmadı (6,2±0,7 mm vs. 6,1±0,7 mm, $p=0,324$).

Sonuç: PFDC, CM1 hastalarında serebellar tonsil ektopisini anlamlı biçimde azaltarak posterior fossada etkili anatomik dekompresyon sağlar. DOI'deki hafif düşüş BOS akımında kısmi iyileşmeyi

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Abstract

flow analysis are warranted to better define radiological predictors of surgical success.

Keywords: Cerebrospinal fluid dynamics, Chiari type I malformation, morphometry, posterior fossa decompression, tonsillar ectopia

Öz

düşündürürken, MPD'nin değişmemesi beyin sapı pozisyonunun büyük ölçüde sabit kaldığını göstermektedir. Dinamik BOS akım analizini de içeren daha geniş prospektif çalışmalar, cerrahi başarının radyolojik belirteçlerini daha net tanımlayabilir.

Anahtar kelimeler: Beyin omurilik sıvısı dinamikleri, Chiari tip I malformasyonu, morfometri, posterior fossa dekompresyonu, tonsiller ektopi

Introduction

Chiari type I malformation (CM1) is a congenital condition defined by herniation of the cerebellar tonsils through the foramen magnum, usually associated with a small posterior cranial fossa and disturbed cerebrospinal fluid (CSF) circulation. Patients may present with occipital headache, neck pain, or disequilibrium due to altered CSF flow at the craniocervical junction. In recent years, magnetic resonance imaging (MRI)–based morphometric measurements have gained importance for both diagnostic and prognostic assessment (1-4).

Key morphometric parameters include the mammillopontine distance (MPD), displacement of the iter (DOI), and Boogard angle (BooA), which together describe the spatial relationship of the brainstem, cerebellum, and cranial base. Because the clivus, basion, and opisthion are stable osseous landmarks, BooA remains constant and can serve as a reliable reference point, particularly when postoperative imaging limits direct visualization of the foramen magnum (5,6).

Morphometric analysis also assists in distinguishing CM1 from other conditions presenting with tonsillar ectopia (TE), such as spontaneous intracranial hypotension, which may appear similar on MRI. Parameters like the DOI and MPD are particularly useful in differentiating congenital tonsillar descent from secondary sagging due to CSF volume loss (4,5,7,8). Thus, precise morphometric assessment supports both accurate diagnosis and appropriate surgical selection.

Posterior fossa decompression is the standard treatment for symptomatic CM1, aiming to restore CSF circulation and relieve neural compression at the foramen magnum. However, how decompression alters morphometric indices remains unclear. Defining these radiological changes may help clarify the pathophysiology of CM1 and provide objective markers of surgical success (4,9-11).

This study aimed to evaluate how posterior fossa decompression affects key morphometric parameters, TE, DOI, and MPD in patients with CM1. We hypothesized that decompression would significantly reduce tonsillar descent and modify morphometric indices reflecting improved CSF flow.

Materials and Methods

Ethical Statement

This study was conducted in accordance with the principles of the Declaration of Helsinki. Ethical approval was obtained from the Institutional Review Board of İstanbul University, İstanbul Faculty of Medicine (decision number: 23, date: 14.11.2025) prior to data collection. As this research involved retrospective analysis of existing medical records and imaging studies, the requirement for informed consent was waived by the ethics committee. All patient data were anonymized to ensure confidentiality and privacy.

Study Design

This retrospective study was conducted at İstanbul University, İstanbul Faculty of Medicine, between 2015 and 2024. Demographic data, clinical presentations, neuroradiological imaging, surgical details, and postoperative findings were retrospectively reviewed from medical records.

Inclusion and Exclusion Criteria

Inclusion criteria were: (1) age ≥18 years; (2) cerebellar TE >5 mm below the foramen magnum on MRI; (3) diagnosis of CM1; (4) treatment with posterior fossa decompression surgery (PFDS); and (5) availability of adequate pre- and postoperative MRI scans suitable for morphometric analysis.

Exclusion criteria included previous cranial or cervical surgery, associated craniovertebral anomalies such as atlantoaxial dislocation or basilar invagination, and lack of postoperative imaging or consent.

Patient Selection and Statistical Plan

A total of 39 patients who underwent surgery for CM1 were screened. Sixteen were excluded due to incomplete or low-quality postoperative imaging, leaving 23 patients for final analysis. Quantitative variables were expressed

as mean ± standard deviation (SD). Three separate paired t-tests were performed to compare preoperative and postoperative TE, DOI, and MPD values. Because three related paired comparisons were conducted, the issue of multiple comparisons was considered. However, no formal correction (e.g., Bonferroni adjustment) was applied, and unadjusted p-values are reported. A p-value <0.05 was considered statistically significant. DOI and MPD analyses should therefore be interpreted as exploratory.

No a priori power or sample size calculation was performed for this study. The final sample size was determined by the number of eligible patients who met the inclusion criteria during the study period and had complete and adequate pre- and postoperative MRI data available for morphometric analysis. As this was a retrospective single-center study, the cohort size was determined by available data rather than a predefined statistical estimate.

Image Analysis

Based on the median sagittal plane, TE, MPD, DOI, and BooA were obtained. All measurements were obtained on sagittal MRI. TE was defined as the maximum projection of the tonsils below the McRae line, which is drawn between the opisthion and the basion (Figure 1) (12). MPD was defined as the distance between the inferior aspect of the mamillary bodies and the superior aspect of the pons (Figure 1) (13). DOI was determined by measuring a line along the plane of the incisura and measuring the distance to this line to the aperture of the cerebral aqueduct. DOI refers to the displacement of the third ventricular aperture of the cerebral aqueduct from the plane of the incisura; as the value becomes negative, the part below the incisura increases (Figure 2) (13,14). BooA is an angle that is used to determine the McRae line after posterior fossa decompression surgery. In the preoperative MRI, in addition to the line drawn from the basion to the opisthion, Wackenheim's clivus canal line is drawn from the clivus to the basion. The angle calculated at the intersection of the two lines is the BooA. Postoperatively, a virtual McRae line can be created by drawing a horizontal line at the BooA along the Wackenheim line passing through the basion (Figure 3). Thanks to BooA, TE after the posterior fossa decompression surgery can be measured.

All morphometric measurements (TE, DOI, MPD, and BooA) were independently performed on the same mid-sagittal MRI slice by two observers blinded to the timing of imaging (preoperative vs. postoperative). Interobserver reliability was assessed using the intraclass correlation coefficient (ICC; two-way random-effects model, absolute agreement). Excellent agreement was observed for TE [ICC =0.92; 95% confidence interval (CI) 0.83-0.96], DOI (ICC =0.88; 95% CI 0.76-0.94), and MPD (ICC =0.90; 95% CI 0.80-0.95). Discrepant measurements (>1 mm for TE/MPD or

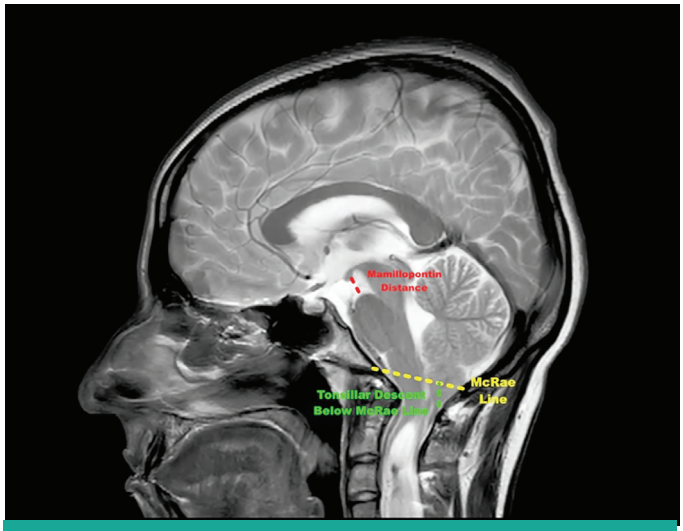

Figure 1. Measurement of tonsillar ectopia (TE) and mammillopontine distance (MPD) on mid-sagittal magnetic resonance imaging. The McRae line is drawn between the basion and opisthion. TE is defined as the maximum vertical distance of the cerebellar tonsils below this line. MPD is measured between the inferior margin of the mammillary bodies and the superior surface of the pons

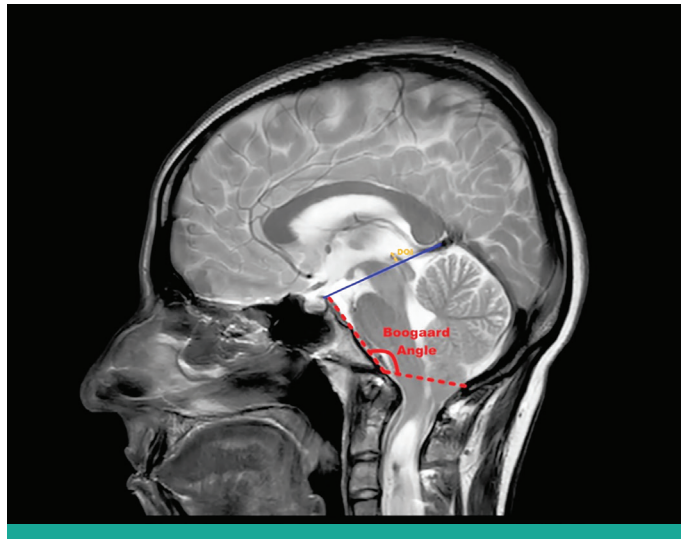

Figure 2. Measurement of Boogard's angle (BooA) and displacement of the iter (DOI) on mid-sagittal magnetic resonance imaging. BooA is formed by the intersection of Wackenheim's clivus canal line and the basion-opisthion line. DOI is determined by drawing a reference line along the plane of the tentorial incisura and measuring the perpendicular distance from this line to the cerebral aqueduct opening, representing the vertical displacement of the midbrain relative to the incisural plane

>0.5 mm for DOI) were resolved by consensus review.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows, version 26.0 (IBM Corp., Armonk, NY, USA). Quantitative variables were expressed as mean ± SD. The Shapiro-Wilk test was used to assess the normality of data distribution. Preoperative and postoperative morphometric measurements were compared using paired t-tests. Interobserver reliability was evaluated using ICC with 95% CIs. A p-value <0.05 was considered statistically significant.

Results

A total of 23 patients who met the inclusion criteria were analyzed. The mean age was 34.0±8.7 years, and most were female (n=19, 82.6%), while 4 (17.4%) were male (Table 1). The mean preoperative TE was 10.9±2.8 mm, the MPD was 6.2±0.7 mm, and the DOI was 4.2±0.9 mm. Postoperatively, these values were 6.9±2.5 mm, 6.1±0.7 mm, and 3.9±0.8 mm, respectively (Table 2). TE decreased by a mean of 4.0 mm (95% CI -5.1 to -2.9; p=0.0003). DOI showed a small mean decrease of 0.3 mm (95% CI -0.60 to -0.00; p=0.048). In contrast, MPD demonstrated no significant change (mean difference -0.05 mm; 95% CI -0.15 to 0.05; p=0.324). Interobserver agreement was excellent across morphometric measurements (ICC range 0.88-0.92).

Statistical analysis demonstrated a significant postoperative reduction in TE compared with preoperative measurements (p<0.02). DOI showed a small decrease postoperatively (p=0.048, unadjusted). Given that three paired comparisons were performed and no correction for multiple testing was applied, this finding should be interpreted with caution. In contrast, the change in MPD was not statistically significant (p=0.324). No postoperative complications, CSF leakage, or wound infections were noted during follow-up. The reduction in TE was consistent across both male and female patients, with no significant sex-related difference in morphometric change. Postoperatively, most patients reported subjective improvement in headache and neck pain during routine clinical follow-up, consistent with expected symptomatic benefit after PFDS. Given the retrospective design, formal symptom scoring was not uniformly available and therefore was not included in statistical correlation analyses.

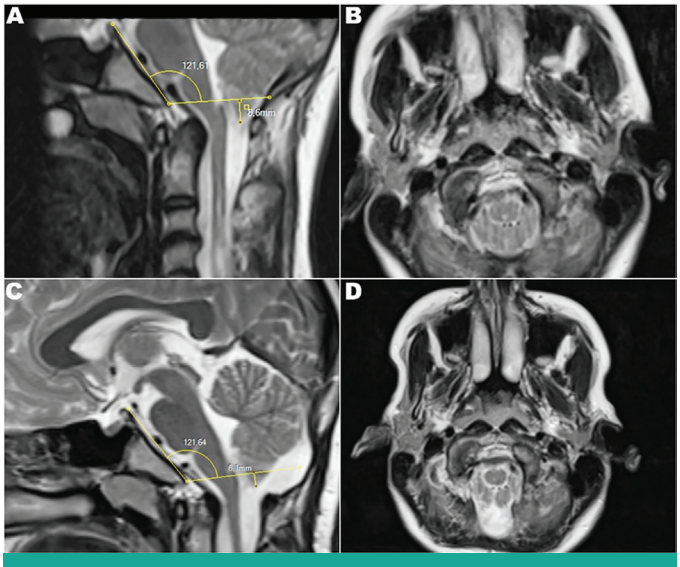

Figure 3. Postoperative reconstruction of the McRae line using Boogard's angle (BooA). After posterior fossa decompression, when the opisthion is no longer identifiable, a virtual McRae line can be reconstructed by projecting a horizontal line at the level of the BooA along Wackenheim's clivus canal line passing through the basion. This allows standardized measurement of tonsillar ectopia on postoperative magnetic resonance imaging

Discussion

CM1 is defined by herniation of the cerebellar tonsils through the foramen magnum, leading to disturbed CSF circulation and compression of posterior fossa structures. Although its pathophysiology has been extensively described, differentiating CM1 from conditions such as spontaneous intracranial hypotension remains clinically challenging because of overlapping radiological features. Previous reports have shown that up to one-third of patients with spontaneous intracranial hypotension were initially misdiagnosed as having CM1, resulting in delayed treatment and unnecessary surgery (12).

Morphometric parameters measured on MRI, such as TE, DOI, and MPD, have been proposed as objective markers to evaluate posterior fossa morphology and CSF dynamics

Table 1. Demographic characteristics of patients with Chiari type I malformation who underwent posterior fossa decompression surgery

Variable	n (%)/mean ± SD
Total patients included	39
Excluded (no postoperative imaging)	16
Patients analyzed	23
Female	19 (82.6%)
Male	4 (17.4%)
Mean age (years)	34.0±8.7

Data are expressed as the number of patients (n) and percentage (%) or mean ± standard deviation (SD), as appropriate

Table 2. Comparison of preoperative and postoperative morphometric measurements in patients with Chiari type I malformation

Parameter	Preoperative (mean ± SD)	Postoperative (mean ± SD)	Mean change (mm)	p-value
Tonsillar descent below McRae line (mm)	10.9±2.8	6.9±2.5	-4.0 (95% CI -5.1 to -2.9)	0.0003
DOI length (mm)	4.2±0.9	3.9±0.8	-0.3 (95% CI -0.60 to -0.00)	0.048
Mamillopontine distance (mm)	6.2±0.7	6.1±0.7	-0.05 (95% CI -0.15 to 0.05)	0.324 NS

Data are presented as mean ± standard deviation (SD). Statistical analysis was performed using paired t-tests comparing pre- and postoperative values. p<0.05 was considered statistically significant; NS: Not significant, DOI: Displacement of the iter, CI: Confidence interval

(13,14). Among these, TE provides a direct anatomical indicator of neural descent, while DOI and MPD are thought to reflect the effect of altered intracranial pressure and brainstem position.

In the present study, TE significantly decreased following posterior fossa decompression surgery (PFDS), confirming that surgical decompression effectively corrects the anatomical descent of the cerebellar tonsils. This finding is consistent with previous studies demonstrating radiological reversal of tonsillar herniation after PFDS and correlating this with clinical improvement (4,9,11,15). The significant but modest reduction in DOI observed here may indicate partial restoration of normal CSF pathways at the level of the incisura. However, the absence of a significant change in MPD suggests that the brainstem and mammillary body position remain relatively stable postoperatively, implying that decompression primarily affects the posterior fossa and foramen magnum region rather than midbrain alignment. Although clinical outcome measures were not formally analyzed, the observed reduction in TE and DOI may provide anatomical context for the symptomatic improvement commonly reported after decompression surgery. Future prospective studies incorporating standardized symptom scoring could further clarify whether the magnitude of morphometric change directly correlates with clinical improvement.

Our results contribute to the growing evidence that morphometric measurements can complement clinical assessment in postoperative follow-up of CM1 patients. Quantitative evaluation using BooA-based reconstruction of the McRae line also proved useful for standardizing TE measurement when the posterior fossa is surgically altered. This method allows consistent comparison between preoperative and postoperative MRIs, addressing one of the common limitations in morphometric CM1 research.

Study Limitations

The study has several limitations. First, the sample size was relatively small and derived from a single center, which may limit the generalizability of the findings. Importantly, no a priori power analysis was conducted, and the final cohort size was determined by the availability of eligible retrospective cases with complete imaging data. As a result, the study may have been underpowered to detect smaller effect sizes. This is particularly relevant for parameters demonstrating borderline statistical significance, such as the DOI, where limited statistical power may have influenced the robustness of the observed associations. Additionally, CSF flow was not directly measured with cine-MRI or invasive pressure monitoring; therefore, interpreting DOI as a surrogate for CSF dynamics remains indirect. Nevertheless, measurements were performed using standardized imaging planes, and interobserver agreement was excellent based on ICC analysis, supporting the reliability of the morphometric outcomes. The lack of correction for multiple comparisons increases the risk of type I error, particularly for the borderline DOI finding (p=0.048).

Future studies with larger cohorts and incorporation of dynamic CSF flow imaging or volumetric posterior fossa analysis could further clarify the radiological correlates of clinical improvement after PFDS. Longitudinal analyses may also help identify which morphometric changes best predict symptomatic relief or recurrence in CM1. These morphometric parameters may ultimately serve as objective imaging biomarkers in evaluating surgical outcomes and guiding postoperative management in CM1 patients.

Conclusion

Posterior fossa decompression surgery (PFDS) effectively reduces cerebellar TE in patients with CM1, confirming the anatomical success of decompression. The modest postoperative decrease in DOI may reflect partial restoration of CSF flow, whereas the stable MPD suggests limited impact on brainstem position. Future prospective studies integrating morphometric parameters with dynamic CSF flow assessment using cine MRI may improve the ability to correlate anatomical decompression with physiological restoration and clinical outcomes. Combining structural morphometry with cine MRI-based CSF flow metrics could

provide a more comprehensive postoperative imaging framework and enhance the translational value of MRI in CM1.

Ethics

Ethics Committee Approval: This study was conducted in accordance with the principles of the Declaration of Helsinki. Ethical approval was obtained from the Institutional Review Board of İstanbul University, İstanbul Faculty of Medicine (decision number: 23, date: 14.11.2025) prior to data collection.

Informed Consent: This research involved retrospective analysis of existing medical records and imaging studies, the requirement for informed consent was waived by the ethics committee. All patient data were anonymized to ensure confidentiality and privacy.

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Footnotes

Authorship Contributions

Surgical and Medical Practices: D.D.B., C.İ.G., Concept: D.D.B., S.Ö., F.K., T.C.Ü., İ.D., P.A.S., A.A., Y.A., A.S., Design: C.İ.G., S.Ö., T.C.Ü., İ.D., P.A.S., A.A., Y.A., A.S., Data Collection or Processing: D.D.B., C.İ.G., S.Ö., T.C.Ü., İ.D., P.A.S., Y.A., A.S., Analysis or Interpretation: D.D.B., C.İ.G., S.Ö., F.K., A.A., Y.A., A.S., Literature Search: C.İ.G., F.K., P.A.S., Writing: D.D.B., C.İ.G., S.Ö., F.K.

Conflict of Interest: No conflict of interest was declared by the authors.

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References

1. Alpergin BC, Eroglu U, Yakar F, Karadagoglu U, Ozpiskin OM, Gokalp E, et al. Radioanatomical assessment of the sphenoid ridge in Chiari type I malformation. Turk Neurosurg. 2025;35(4):661-666.
2. Yücel A, Dolgun H, Bahadir B, Kavcar M, Şener B, Kurtoğlu M, et al. Crista galli in Chiari malformation type 1: a retrospective study on CT. J Craniofac Surg. 2025. Epub ahead of print.
3. Wang B, Chen SC, Zhang YW, Liu WH, Wang C, Liu YX, et al. A novel metric for assessing long-term outcomes in adults with Chiari malformation type I: occipitocervical dura angulation (ODA)-applications and value. Cerebellum. 2025;24(4):107.
4. Piper RJ, Afshari FT, Soon WC, Dyson EW, Ekert J, Cearns MD, et al. Quality-of-life outcomes in adults and children with Chiari 1 malformation and in those managed without surgery: a prospective, multicenter, observational study. Neurosurgery. 2025. Epub ahead of print.
5. Patel AA, Davison MA, Shost MD, Kshettry VR, Krishnaney AA, Recinos V, et al. Validation of PROMIS score as a measure of postoperative success following decompressive surgery for Chiari I malformation. Clin Neurol Neurosurg. 2025;252.
6. Montgomery EY, Caruso JP, Price AV, Whittemore BA, Weprin BE, Swift DM, et al. Predictors of syrinx presentation and outcomes in pediatric Chiari malformation type I: a single institution experience of 218 consecutive syrinx patients. Childs Nerv Syst. 2024;40(8):2527-2534.
7. Haciyakupoglu E, Yüvrük E, Yilmaz DM, Polat S, Haciyakupoğlu S. Duraplasty with autologous blood: a cost-effective and efficient alternative to medical products. J Neurol Surg A Cent Eur Neurosurg. 2026. Epub ahead of print.
8. Badrani JH, Caudill C, Paik KS, Anderson L, Leon TJ, Rocque BG, et al. Validation of fourth ventricle roof angle as a measure of brainstem dysfunction in pediatric Chiari malformation type I. J Neurosurg Pediatr. 2025;36(6):694-701.
9. Pema P, Monahan D, Patel S, Patel NV, Zhao K. Minimally invasive decompression for Chiari I malformation: a systematic review and meta-analysis. Cureus. 2025;17(7):e89016.
10. Gallo P, Afshari FT, Stendall C, Kaliaperumal C, Cheung M. A comparison of prone versus sitting position for the surgical treatment of Chiari malformation type I in children. J Clin Neurosci. 2025;139:111429.
11. Park H, Kim W, Sim J, Myeong H, Kim JH, Lee CH, et al. Comparison of suboccipital craniectomy versus suboccipital cranioplasty in foramen magnum decompression for adult Chiari malformation. J Neurosurg Spine. 2025;43(2):1-9.
12. Schievink WI. Misdiagnosis of spontaneous intracranial hypotension. Arch Neurol. 2003;60(12):1713-1718.
13. Shah LM, McLean LA, Heilbrun ME, Salzman KL. Intracranial hypotension: improved MRI detection with diagnostic intracranial angles. AJR Am J Roentgenol. 2013;200(2):400-407.
14. Young SJ, Quisling RG, Bidari S, Sanghvi TS. An objective study of anatomic shifts in intracranial hypotension using four anatomic planes. Radiol Res Pract. 2018;2018:6862739.
15. Aboulezz AO, Sartor K, Geyer CA, Gado MH. Position of cerebellar tonsils in the normal population and in patients with Chiari malformation: a quantitative approach with MR imaging. J Comput Assist Tomogr. 1985;9(6):1033-1036.